

Appl. No. 09/938,205
Amdt. dated Monday, October 20, 2003
Reply to Official Action of July 29, 2003

Amendments to the Claims:

This listing of claims will replace all prior versions and listings of claims in the application:

Listing of Claims:

Claim 1. (currently amended) A process of manufacturing a metal sheet precoated with an antimicrobial polymer coating, comprising:

providing a metal sheet substrate having two opposed planar surfaces comprising a base metal selected from the group consisting of aluminum, iron, nickel, titanium, molybdenum, magnesium, manganese, copper, silver, lead, tin, chromium, beryllium, tungsten, cobalt and alloys thereof;

cleaning the surface of the substrate with an alkaline solution comprising one or more agents selected from the group consisting of caustic soda, soda ash, alkaline silicates, sodium hydroxide, sodium carbonate, sodium metasilicate, phosphates, alkaline builders, ammonium acid phosphate, ammonium hydroxide, monoethanol amine, and dimethylamine oxide wherein cleaning comprises removing bulk and molecular organic contaminants;

pretreating at least one planar surface of the substrate to promote adhesion of a polymer coating;

applying a polymer coating onto at least one planar surface of the substrate by roll coating the substrate with a polymer containing an anti-microbial powder comprising core particles associated with an antimicrobial metal component;

wherein the content of the antibiotic powder is in the range of from about 0.2 to about 30 weight percent of the polymeric coating;

wherein the core particle comprises one or more particles selected from the group

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consisting of: oxides selected from the group consisting of titanium, aluminum, zinc and copper oxides, sulfates selected from the group consisting of calcium, strontium and barium sulfates, sulfides selected from the group consisting of zinc and copper sulfides, zeolites, zirconium phosphate, mica, talc, kaolin, mullite, silica and mixtures thereof;

wherein the antimicrobial metal component is selected from the group consisting of silver, copper, zinc, mercury, tin, lead, bismuth, cadmium, chromium, cobalt, nickel, and thallium ions and mixtures thereof; and

treating the coated substrate to produce at least a partially hardened and adhered antimicrobial coating on the final sheet product.

- Claim 2. (original) The process of claim 1 wherein the base metal is a metal selected from the group consisting of steel, zinc, iron, aluminum, copper and mixtures thereof.
- Claim 3. (original) The process of claim 2 wherein the metal sheet is provided as a continuous strip.
- Claim 4. (previously presented) The process of claim 3 wherein the base metal is selected from the group consisting of steel alloys, zinc coated steel, aluminum coated steel, zinc aluminum coated steel, zinc alloys, aluminum alloys and nickel alloys.
- Claim 5. (original) The process of claim 3 wherein the base metal is a nickel alloy selected from the group consisting of nickel manganese, nickel-aluminum, nickel silver, nickel bronze and nickel-silicon.
- Claim 6. (previously presented) The process of claim 3 wherein the base metal is selected from the group consisting essentially of copper alloys, brass, bronze, silicon bronze, silicon brass, nickel silver and nickel bronze.

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- Claim 7. (original) The process of claim 3 wherein the base metal is an aluminum-based metal selected from the group consisting of pure aluminum, aluminum oxide, and aluminum alloy.
- Claim 8. (original) The process of claim 7 wherein the base metal is an aluminum alloy selected from the group consisting of Al-Cl, Al-Mg, Al-Si, Al-Cu-Ni-Mg and Al-Si-Cu-Ni-Mg.
- Claim 9. (original) The process of claim 3 wherein the base metal is an iron-based metal selected from the group consisting of pure iron, iron oxide, carbon steel, Ni steel, Cr steel, Ni-Cr steel, Cr-Mo steel, Ni-Cr-Mo steel, stainless steel, silicon steel, Permalloy, non-magnetic steel, magnetic steel, and cast steel.
- Claim 10. (original) The process of claim 3 wherein the base metal is an alloy steel selected from the group consisting of carbon steel, Ni steel, Cr steel, Ni-Cr steel, Cr-Mo steel, stainless steel, silicon steel and Permalloy.
- Claim 11. (original) The process of claim 3 wherein the base metal is galvanized steel.
- Claim 12. (canceled)
- Claim 13. (canceled)
- Claim 14. (currently amended) The process of ~~claim 13 wherein~~ claim 1 wherein the alkaline solution additionally contains one or more of the agents selected from the group consisting of complexing agents, surfactants, sequestrant, builders, surface-active agents, defoaming agents, and mixtures thereof.
- Claim 15. (original) The process of claim 14 wherein the alkaline builder comprises one or more of the agents selected from the group consisting of sodium silicate, trisodium phosphate, caustic soda, disodium phosphate, sodium pyrophosphate, sodium carbonate, sodium bicarbonate, sodium tripolyphosphate, and sodium sesquicarbonate.

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- Claim 16. (currently amended) The process of ~~claim 13 wherein~~ claim 1 wherein the temperature of the alkaline solution is between about 25° and about 95°C.
- Claim 17. (currently amended) The process of ~~claim 12 wherein~~ claim 1 wherein the metal surface having been contacted by the cleaning solution is rinsed with water.
- Claim 18. (original) The process of claim 17 wherein the rinsing is followed by drying.
- Claim 19. (currently amended) The process of ~~claim 13 wherein~~ claim 1 wherein the pretreating creates a chemical conversion interlayer coating selected from the group consisting of a silane, phosphate, chromate, epoxy, oxide, adhesive and mixtures thereof.
- Claim 20. (original) The process of claim 19 wherein the interlayer is formed by contacting the metal with a composition selected from the group consisting of chromium phosphate, chromium chromate, zinc phosphate, iron phosphate, or an epoxy.
- Claim 21. (original) The process of claim 20 wherein the interlayer is formed by contacting the metal with an aqueous phosphating composition comprising phosphoric acid and a divalent metal ion wherein the composition has total phosphate content from about 0.01 to about 3 moles/liter and the metal ion is selected from the group consisting of divalent transition metal ions and alkaline earth divalent metal ions.
- Claim 22. (original) The process of claim 21 wherein the divalent metal ion is selected from the group consisting of Mn, Co, Fe, Ni, and Zn.
- Claim 23. (original) The process of claim 21 wherein the divalent metal ion is selected from the group consisting of Mg, Ca, Sr, and Ba.
- Claim 24. (original) The process of claim 21 wherein the divalent metal ion is selected from the group consisting of Fe, Ni and Zn.

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Claim 25. (original) The process of claim 24 wherein the phosphating composition additionally comprises an oxidant is selected from the group consisting of bromate, chlorate, nitrate, nitrite, organic nitro compounds, perborate, persulfate or hydrogen peroxide, m-nitrobenzene sulfonate, nitrophenol and combinations thereof.

Claim 26. (original) The process of claim 24 wherein the phosphating composition additionally comprises one or more compounds selected from the group consisting of sulfate, fluoride, silicofluoride, boron fluoride, citrate, tartrate, hydroxy-carboxylic acids, aminocarboxylic acids, condensed phosphates, silicates, alkali metal metasilicate, alkali metal orthosilicate, and alkali metal disilicate.

Claim 27. (original) The process of claim 24 wherein the phosphating composition additionally comprises silicate.

Claim 28. (original) The process of claim 21 wherein the metal substrate is predominantly aluminum and wherein the phosphating composition includes an activator present as fluoride ions in amounts up to 1.0 moles/liter.

Claim 29. (previously presented) The process of claim 21 wherein the metal substrate is predominantly galvanized steel or steel and wherein the phosphating composition includes boric acid in an amount of at least 0.02 moles/liter.

Claim 30. (original) The process of claim 24 wherein the interlayer is between about 0.01 to about 30 microns thick.

Claim 31. (original) The process of claim 24 wherein the interlayer is at least partially dried by heating.

Claim 32. (original) The process of claim 31 wherein the drying temperature is between about 25° and about 95°C.

Claim 33. (original) The process of claim 31 where in the drying temperature is from at least 50°C.

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Claim 34. (currently amended) The process of ~~claim 13 wherein~~ claim 1 wherein the polymer is an organic polymer material selected from the group consisting of acetate rayon, acrylic resins, acrylonitrile-butadiene-styrene resins and acrylic resins, aliphatic and aromatic polyamides, aliphatic and aromatic polyesters, allyl resins, butadiene resins, chlorinated polyethylene, conductive resins, copolymerised polyamides, copolymers of ethylene and vinyl acetate, cuprammonium rayons and natural and synthetic rubbers, EEA resins, epoxy resins, ether ketone resins, ethylene vinyl alcohol, fluorine resins, fluorocarbon polymers, fluoroplastics, high density polyethylenes, ionomer resins, liquid crystal polymer, low density polyethylenes, melamine formaldehyde, natural polymers, nylons, phenol-formaldehyde plastic, phenolic resins, polyacetal, polyacrylates, polyacrylonitrile, polyamide, polyamide-imide, polyaryletherketone, polybutadiene, polybutylene terephthalate, polybutylene, polycarbonate, polycarbonates, polydicyclopentadiene, polyketones, polyester block copolymers, polyesters, polyesterurethane, polyesterurethaneurea, polyether and polyester block polymers, polyether ketoneketone polyetherether ketone polyetherimide, polyethers, polyethersulfone, polyetherurethane, polyetherurethaneurea, polyethylene isophthalate, polyethylene terephthalate, polyethylenec, polyethylenechlorinates, polyglycolic acid, polyhexamethylene terephthalate, polyimide, polylactic acid, polymethylpentene, poly-m-phenylene isophthalamide, polyolefins, polyphenylene oxide, polyphenylene sulfide, polyphthalamide, poly-p-phenylene terephthalamide, polypropylene, polysiloxanes, polystyrene, polysulfides, polysulfone, polytetrafluoroethylene, polyurethane, polyvinyl acetate, polyvinyl alcohols, polyvinylchloride, polyvinylidene chloride, polyvinylidene fluoride and polyvinyl fluoride, rayon, reconstituted silk and polysaccharides, reinforced polyethylene terephthalate resins, segmented polyurethane elastomers, silicone resins, elastane elastomers, styrene-type specific resins, thermoplastic polyurethane elastomers, phenol-formaldehyde copolymer, triacetate rayon, unsaturated polyester resins, urea resins, urethane resins, vinyl chloride resins, vinyl polymers, vinylidene chloride resins and copolymers, terpolymers and mixtures thereof.

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- Claim 35. (original) The process of claim 20 wherein the polymer is selected from the group consisting of acrylic resins, polyester resins, polyethylene, polypropylene, epoxy resins, polyurethane resins, olefin resins, polyamide resins, ethylene-vinyl acetate copolymer, ethylene-vinyl alcohol copolymer, polyvinyl chloride, polyvinylidene chloride, polystyrene, ABS resin, polyethylene terephthalate, nylon, polycarbonate and copolymers, terpolymers and mixtures thereof.
- Claim 36. (original) The process of claim 20 wherein the polymer is selected from the group consisting of aminoalkyd resins, aminoacrylic resins, polyvinyl chloride and polyesters.
- Claim 37. (original) The process of claim 20 wherein the polymer is a polyester.
- Claim 38. (original) The process of claim 20 wherein the polymer is an epoxy selected from the group consisting of phenolic-modified epoxies, polyester-modified epoxies, epoxy-modified polyvinyl chloride, and cross linkable epoxies.
- Claim 39. (original) The process of claim 20 wherein the polymer is an epoxy.
- Claim 40. (original) The process of claim 35 wherein the core particle is a natural zeolite selected from the group consisting of analcime, chabazite, clinoptilolite, erionite, faujasite, mordenite, and phillipsite.
- Claim 41. (original) The process of claim 35 wherein the core particle is a synthetic zeolite selected from the group consisting of A-type zeolite, X-type zeolite, Y-type zeolite, and mordenite.
- Claim 42. (original) The process of claim 41 wherein the core particle is a synthetic zeolite whose ion-exchangeable ions are partially or completely ion-exchanged with antibiotic metal ions.
- Claim 43. (original) The process of claim 42 wherein the ion-exchangeable ions are selected from the group consisting of sodium ions, potassium ions, calcium ions, magnesium ions and iron ions and wherein the antibacterial metals ions are

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selected from the group consisting of silver, copper, zinc, mercury, tin, lead, bismuth, cadmium, chromium, cobalt, nickel, and thallium ions or mixtures thereof, and wherein the zeolite particles retain the antibacterial metal ions at ionic exchange sites of the zeolite in an amount less than the ion exchange saturation capacity of the zeolite.

Claim 44. (original) The process of claim 43 wherein the zeolite is ion-exchanged with metal ions in an amount less than about 90% of the ion-exchangeable saturation capacity of the zeolite particles.

Claim 45. (original) The process of claim 44 wherein the antibacterial metals ions are selected from the group consisting of silver, copper or zinc ions or mixtures thereof.

Claim 46. (original) The process of claim 44 wherein the antibacterial metal ions are silver.

Claim 47. (original) The process of claim 45 wherein additional metal ions selected from the group consisting of sodium, potassium, magnesium, calcium, aluminum, titanium, cerium and ammonium ion co-exist on the zeolite.

Claim 48. (original) The process of claim 44 wherein the amount of antimicrobial component on the core particle is at least about 0.1% by weight, based on anhydrous zeolite plus metal.

Claim 49. (original) The process of claim 44 wherein the amount of antimicrobial component on the core particle is at least about 0.2% by weight, based on anhydrous zeolite plus metal.

Claim 50. (original) The process of claim 44 wherein the amount of antimicrobial component on the core particle is at most about 20% by weight, based on anhydrous zeolite plus metal.

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- Claim 51. (original) The process of claim 44 wherein the amount of antimicrobial component on the core particle is at most about 15% by weight, based on anhydrous zeolite plus metal.
- Claim 52. (original) The process of claim 44 wherein the amount of antimicrobial component on the core particle is at most about 10% by weight, based on anhydrous zeolite plus metal.
- Claim 53. (previously presented) The process of claim 44 wherein the zeolite is ion-exchanged with one or more additional metal ions selected from the group consisting of silica, silicates, silicon dioxide, borosilicates, aluminosilicates, alumina, aluminum phosphate, zinc, zinc oxide, zinc silicate, copper, copper oxide, and mixtures thereof.
- Claim 54. (previously presented) The process of claim 53 wherein the additional metal ions comprise from about 0.1 to about 20% by weight, based on anhydrous zeolite plus metal.
- Claim 55. (original) The process of claim 44 wherein the antimicrobial powder is additionally coated with a dispersion enhancing coating selected from the group consisting of resin, hydrous metal oxide, and mixtures thereof.
- Claim 56. (original) The process of claim 44 wherein the antimicrobial powder has an average particle size less than about 10 microns.
- Claim 57. (original) The process of claim 44 wherein the antimicrobial powder has an average particle size less than about 6 microns.
- Claim 58. (original) The process of claim 44 wherein the antimicrobial powder has an average particle size greater than about 0.1 microns.
- Claim 59. (original) The process of claim 44 wherein the antimicrobial powder has an average particle size greater than about 0.2 microns.
- Claim 60. (original) The process of claim 44 wherein the polymer further comprises at least one additional component selected from the group consisting of

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defoamers, polymerization catalysts, stabilizers, delustering agents, whitening agents, pigments, fillers, plasticisers, ultraviolet absorbers, antioxidants, light stabilizers, ultraviolet stabilizers, processing stabilizers, and metal deactivators.

Claim 61. (previously presented) The process of claim 44 wherein the roll coater is a two-roll coater.

Claim 62. (original) The process of claim 44 wherein the polymer is applied by two or more coaters placed in series.

Claim 63. (original) The process of claim 61 wherein the antimicrobial polymer coating is applied onto both opposed planar surfaces of the sheet metal.

Claim 64. (original) The process of claim 61 wherein the polymer coating is at least partially hardened by a method selected from the group consisting of heat, infrared radiation, fluorescent radiation, ultraviolet radiation, gamma or beta radiation, X-ray radiation, or combinations thereof.

Claim 65. (original) The process of claim 64 wherein cleaning comprises deoxidizing the surface by immersion in an acid solution, and rinsing in water.

Claim 66. (original) The process of claim 61 wherein the metal sheet is made of a base metal material selected from the group consisting of aluminum, aluminum alloys, magnesium, and magnesium alloys.

Claim 67. (original) The process of claim 61 wherein the metal sheet is stainless steel and wherein the coating has a thickness of from about 1 to about 30 microns.

Claim 68. (original) The process of claim 61 wherein the coating after forming-processed is heated at a temperature of 100° to 300°C.

Claim 69. (currently amended) A metal sheet precoated with an antimicrobial polymer coating manufactured by the method of ~~claim 1, 10, 20, 35 or 42~~ claim 1, 20, 35, 42 or 72.

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Claim 70. (currently amended) A method of increasing stain resistance of a metal sheet by the method of ~~claim 1, 10, 20, 35 or 42~~ claim 1, 20, 35, 42 or 72.

Claim 71. (currently amended) A method of increasing fingerprint resistance of a metal sheet by the method of ~~claim 1, 10, 20, 35 or 42~~ claim 1, 20, 35, 42 or 72.

Claim 72. (new) A process of manufacturing a metal sheet precoated with an antimicrobial polymer coating, comprising:

providing a metal sheet substrate having two opposed planar surfaces comprising a base metal selected from the group consisting of aluminum, iron, nickel, titanium, molybdenum, magnesium, manganese, copper, silver, lead, tin, chromium, beryllium, tungsten, cobalt and alloys thereof;

cleaning the surface of the substrate wherein cleaning comprises removing bulk and molecular organic contaminants;

pretreating at least one planar surface of the substrate to promote adhesion of a polymer coating;

applying a polymer coating onto at least one planar surface of the substrate by roll coating the substrate with a polymer containing an anti-microbial powder comprising core particles associated with an antimicrobial metal component;

wherein the content of the antibiotic powder is at least about 5 weight percent based on the final, dried film weight of the polymeric coating;

wherein the core particle comprises one or more particles selected from the group consisting of: oxides selected from the group consisting of titanium, aluminum, zinc and copper oxides, sulfates selected from the group consisting of calcium, strontium and barium sulfates, sulfides selected from the group consisting of zinc and copper sulfides, zeolites, zirconium phosphate, mica, talc, kaolin, mullite, silica and mixtures thereof;

wherein the antimicrobial metal component is selected from the group consisting of silver, copper, zinc, mercury, tin, lead, bismuth, cadmium, chromium, cobalt,

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nickel, and thallium ions and mixtures thereof; and

treating the coated substrate to produce at least a partially hardened and adhered antimicrobial coating on the final sheet product.

Claim 73. (new) The process of claim 72 wherein the content of the antibiotic powder is at most about 25 weight percent based on the final, dried film weight of the polymeric coating.

Claim 74. (new) A process of manufacturing a metal sheet precoated with an antimicrobial polymer coating, comprising:

providing a metal sheet substrate having two opposed planar surfaces comprising a base metal wherein the base metal is a nickel alloy selected from the group consisting of nickel manganese, nickel-aluminum, nickel silver, nickel bronze and nickel-silicon;

cleaning the surface of the substrate wherein cleaning comprises removing bulk and molecular organic contaminants;

pretreating at least one planar surface of the substrate to promote adhesion of a polymer coating;

applying a polymer coating onto at least one planar surface of the substrate by roll coating the substrate with a polymer containing an anti-microbial powder comprising core particles associated with an antimicrobial metal component;

wherein the content of the antibiotic powder is in the range of from about 0.2 to about 30 weight percent of the polymeric coating;

wherein the core particle comprises one or more particles selected from the group consisting of: oxides selected from the group consisting of titanium, aluminum, zinc and copper oxides, sulfates selected from the group consisting of calcium, strontium and barium sulfates, sulfides selected from the group consisting of zinc and copper sulfides, zeolites, zirconium phosphate, mica, talc, kaolin, mullite, silica and mixtures thereof;

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wherein the antimicrobial metal component is selected from the group consisting of silver, copper, zinc, mercury, tin, lead, bismuth, cadmium, chromium, cobalt, nickel, and thallium ions and mixtures thereof; and

treating the coated substrate to produce at least a partially hardened and adhered antimicrobial coating on the final sheet product.

Claim 75. (new) A process of manufacturing a metal sheet precoated with an antimicrobial polymer coating, comprising:

providing a metal sheet substrate having two opposed planar surfaces comprising a base metal selected from the group consisting of aluminum, iron, nickel, titanium, molybdenum, magnesium, manganese, copper, silver, lead, tin, chromium, beryllium, tungsten, cobalt and alloys thereof;

cleaning the surface of the substrate wherein cleaning comprises removing bulk and molecular organic contaminants;

pretreating at least one planar surface of the substrate to promote adhesion of a polymer coating wherein the pretreating creates a chemical conversion interlayer coating formed by contacting the metal with an aqueous phosphating composition comprising phosphoric acid and a divalent metal ion selected from the group consisting of Mg, Ca, Sr, and Ba;

applying a polymer coating onto at least one planar surface of the substrate by roll coating the substrate with a polymer containing an anti-microbial powder comprising core particles associated with an antimicrobial metal component;

wherein the content of the antibiotic powder is in the range of from about 0.2 to about 30 weight percent of the polymeric coating;

wherein the core particle comprises one or more particles selected from the group consisting of: oxides selected from the group consisting of titanium, aluminum, zinc and copper oxides, sulfates selected from the group consisting of calcium,

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strontium and barium sulfates, sulfides selected from the group consisting of zinc and copper sulfides, zeolites, zirconium phosphate, mica, talc, kaolin, mullite, silica and mixtures thereof;

wherein the antimicrobial metal component is selected from the group consisting of silver, copper, zinc, mercury, tin, lead, bismuth, cadmium, chromium, cobalt, nickel, and thallium ions and mixtures thereof; and

treating the coated substrate to produce at least a partially hardened and adhered antimicrobial coating on the final sheet product.

Claim 76. (new) A process of manufacturing a metal sheet precoated with an antimicrobial polymer coating, comprising:

providing a metal sheet substrate having two opposed planar surfaces comprising a base metal selected from the group consisting of aluminum, iron, nickel, titanium, molybdenum, magnesium, manganese, copper, silver, lead, tin, chromium, beryllium, tungsten, cobalt and alloys thereof;

cleaning the surface of the substrate wherein cleaning comprises removing bulk and molecular organic contaminants;

pretreating at least one planar surface of the substrate to promote adhesion of a polymer coating;

applying a polymer coating onto at least one planar surface of the substrate by roll coating the substrate with a polymer containing an anti-microbial powder comprising core particles associated with a first and second antimicrobial metal component and wherein the core particles retain the first antibacterial metal ions at ionic exchange sites of the particles;

wherein the content of the antibiotic powder is in the range of from about 0.2 to about 30 weight percent of the polymeric coating;

wherein the core particle comprises one or more particles selected from the group consisting of: oxides selected from the group consisting of titanium, aluminum,

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zinc and copper oxides, sulfates selected from the group consisting of calcium, strontium and barium sulfates, sulfides selected from the group consisting of zinc and copper sulfides, zeolites, zirconium phosphate, mica, talc, kaolin, mullite, silica and mixtures thereof;

wherein the first antimicrobial metal component is selected from the group consisting of silver, copper, zinc, mercury, tin, lead, bismuth, cadmium, chromium, cobalt, nickel, and thallium ions thereof;

wherein the second antimicrobial metal component is at least one metal selected from the group consisting of silica, silicates, silicon dioxide, borosilicates, aluminosilicates, alumina, aluminum phosphate, zinc, zinc oxide, zinc silicate, copper, copper oxide, and mixtures thereof; and

treating the coated substrate to produce at least a partially hardened and adhered antimicrobial coating on the final sheet product.

Claim 77. (new) A process of manufacturing a metal sheet precoated with an antimicrobial polymer coating, comprising:

providing a metal sheet substrate having two opposed planar surfaces comprising a base metal selected from the group consisting of aluminum, iron, nickel, titanium, molybdenum, magnesium, manganese, copper, silver, lead, tin, chromium, beryllium, tungsten, cobalt and alloys thereof;

cleaning the surface of the substrate wherein cleaning comprises deoxidizing the surface by immersion in an acid solution, and rinsing in water;

pretreating at least one planar surface of the substrate to promote adhesion of a polymer coating;

applying a polymer coating onto at least one planar surface of the substrate by roll coating the substrate with a polymer containing an anti-microbial powder comprising core particles associated with an antimicrobial metal component;

wherein the content of the antibiotic powder is in the range of from about 0.2 to

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about 30 weight percent of the polymeric coating;

wherein the core particle comprises one or more particles selected from the group consisting of: oxides selected from the group consisting of titanium, aluminum, zinc and copper oxides, sulfates selected from the group consisting of calcium, strontium and barium sulfates, sulfides selected from the group consisting of zinc and copper sulfides, zeolites, zirconium phosphate, mica, talc, kaolin, mullite, silica and mixtures thereof;

wherein the antimicrobial metal component is selected from the group consisting of silver, copper, zinc, mercury, tin, lead, bismuth, cadmium, chromium, cobalt, nickel, and thallium ions and mixtures thereof; and

treating the coated substrate to produce at least a partially hardened and adhered antimicrobial coating on the final sheet product.